Rail Accident Investigation Branch

Rail Accident Report

Accident at Falls of Cruachan, Argyll
6 June 2010

Department for Transport

Report 11/2011
July 2011

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Accident at Falls of Cruachan, Argyll
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Contents

Summary

At 20:55 hrs on Sunday 6 June 2010, the 18:20 hrs train from Glasgow Queen Street to Oban struck a *boulder* that had fallen onto the track just west of the station at Falls of Cruachan, in the Pass of Brander, on the line from Crianlarich to Oban. The boulder lifted up the front coach of the two-coach train and derailed it to the left and down an embankment. The leading bogie of the rear coach came to a stand supported by the boulder with the rear bogie still on the track.

Of the 64 passengers and three crew on the train, eight of the passengers were taken to hospital with minor injuries.

The boulder had fallen down the cutting slope onto the railway from within the railway boundary. It had become insecure due to the growth of tree roots around it, which gradually prised it from its stable position, and soil erosion from normal rainfall. Network Rail's *earthworks* management system applied to cutting slopes had not identified the hazard of loose boulders in the area that the accident occurred.

The RAIB has made five recommendations to Network Rail relating to the management of earthworks. These include:

- improving the clearance of vegetation growing on earthworks so that hazards to the safety of railway operation can be identified;
- improvements to the collection of slope data so that a full appreciation of the condition of slopes is obtained; and
- improvements to the process for the implementation of remediation works to prevent future earthworks failures.

A further recommendation has been made relating to the prevention of lighting diffusers and other saloon panels on rolling stock becoming displaced during accidents.

Preface

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

Key Definitions

3 In this report, speeds are given in imperial units with the equivalent metric value also being given. Distances of specific locations are given in imperial units, in accordance with normal railway practice. Other dimensions are given in metric units.

4 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

5 Left and right are in accordance with the direction of travel of the train involved in this accident.

The Accident

Summary of the accident

6 At 20:55 hrs on Sunday 6 June 2010 train 1Y27, the 18:20 hrs from Glasgow Queen Street to Oban, struck a boulder that had fallen onto the track just west of the station at Falls of Cruachan, in the Pass of Brander, on the line from Crianlarich to Oban. The boulder had fallen onto the track from its position on the slope within the railway boundary because of *root jacking* and soil erosion.

7 The evidence from the site of the accident was that the train, consisting of a 2-car class 156 *diesel multiple unit*, drove over the boulder, which lifted up the front car and derailed it to the left and down an embankment (figure 1). The leading bogie of the rear car ended up supported by the boulder with the rear bogie still on the track (figure 2).

Figure 1: The derailed train following the accident

8 A brief *flash fire* occurred when the boulder seriously damaged the engine and fuel tank of the leading car, but the fire did not enter the interior of the train.

9 There were 64 passengers and three crew on the train. Eight of the passengers were taken to hospital with minor injuries.

Figure 2: Final position of boulder under the leading bogie of the rear car

Organisations and people involved

10 Network Rail is the infrastructure manager of the line where the accident occurred and is responsible for managing the risks from earthworks which could affect the safety of trains.

11 Network Rail's Scotland Route geotechnical team, based in Glasgow, was responsible for monitoring the earthworks *examination* process carried out by a contractor; carrying out *evaluations*, and developing a programme for implementing remedial works where these were required to ensure continuing safety.

12 A specialist firm in civil, structural and geotechnical engineering was contracted by Network Rail to carry out examinations of earthworks, including the slope from which the boulder fell.

13 First ScotRail was the operator of the train involved in the accident and the employer of the three crew on the train: the driver, the conductor and the customer host.

14 Network Rail, the examination contractor and First ScotRail freely co-operated with the RAIB's investigation.

Location

15 The accident occurred at a mileage of 53 miles 330 yards[1], 572 yards (523 metres) west of the station at Falls of Cruachan on the single track railway from Crianlarich to Oban (figure 3). At this point, the line runs through an area known as the Pass of Brander on a shelf cut into the hillside about 42 metres above sea level.

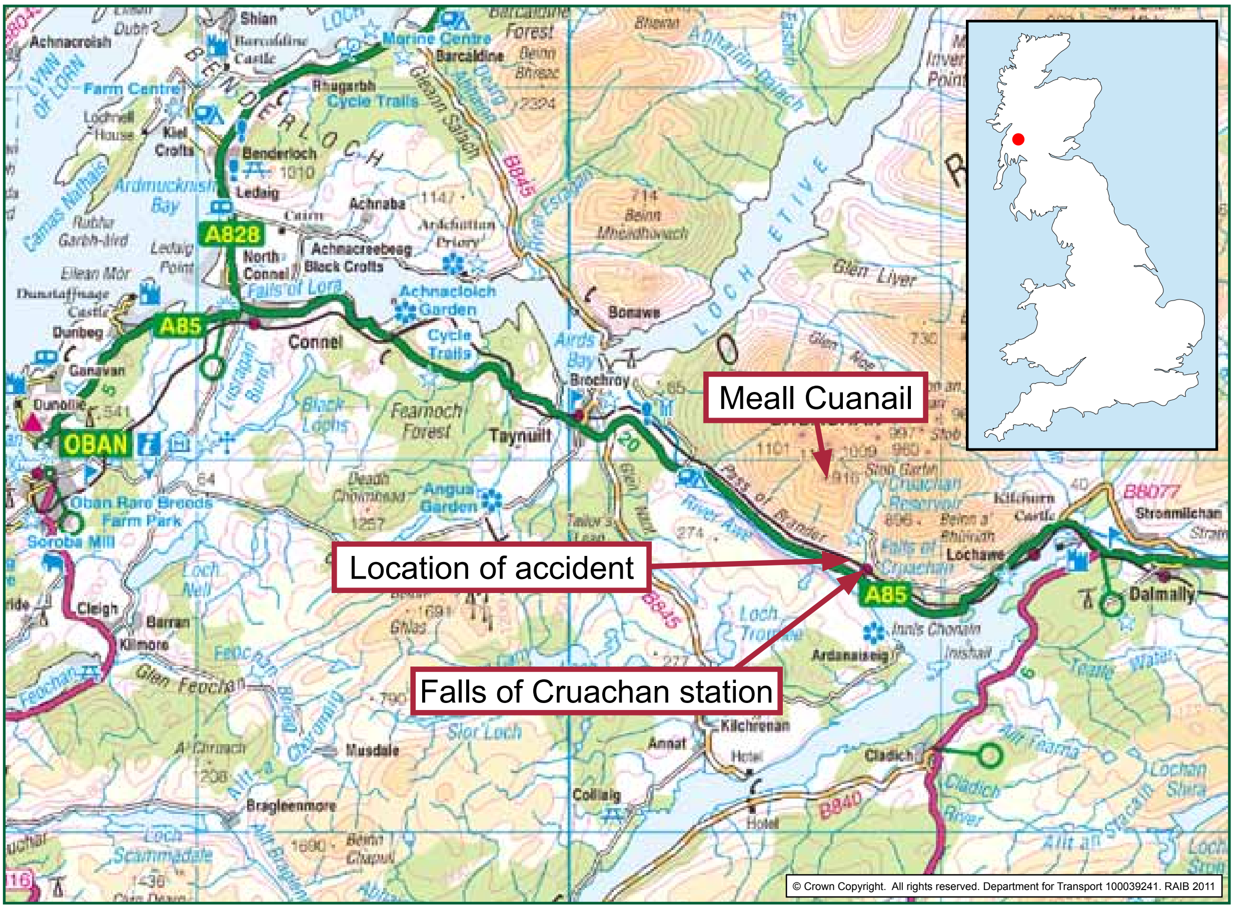


Figure 3: Extract from Ordnance Survey map showing the location of the accident

16 Immediately north of Falls of Cruachan, the natural hillside rises from the railway to the summit of Meall Cuanail (918 metres), an outlying top of Ben Cruachan. On the south side of the railway, a slope leads down to the A85 road and Loch Awe. The Pass of Brander extends from 51 miles 1320 yards to 56 miles (figure 4).

[1] The mileage is measured from a zero datum at Callander, although the section of line between there and Crianlarich was closed in 1965.

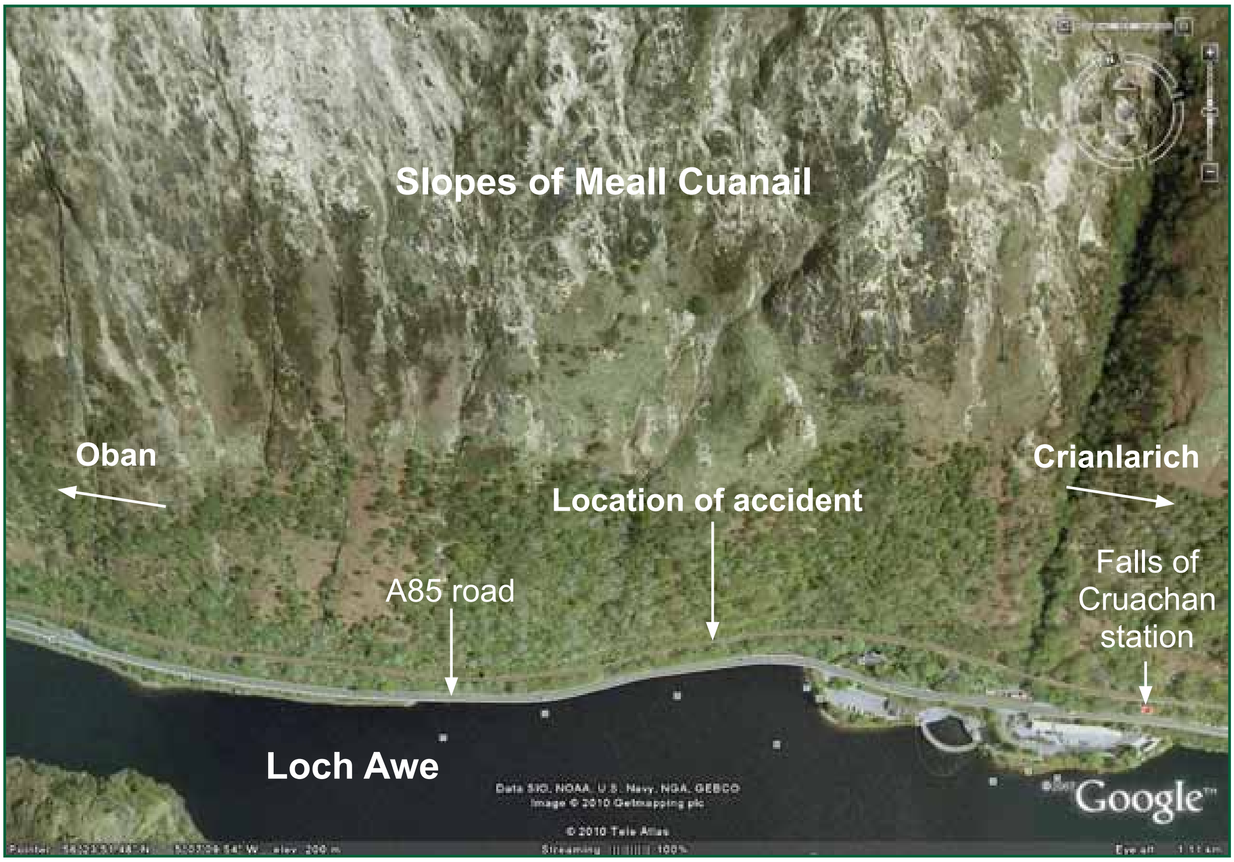


Figure 4: Overview of the accident site (image courtesy of Google Earth)

Infrastructure

17 In the vicinity of the accident, the embankment slope on the south side of the railway leads down to the A85 road and Loch Awe at an angle of 40 to 45 degrees. At the time of the accident, it was heavily vegetated with grass, bramble, small shrubs and mature trees.

18 The cutting slope on the north side of the railway is dotted with boulders and generally rises at between 30 and 35 degrees towards the railway boundary, about 15 metres above the foot of the slope. Beyond the railway boundary, the slope rises at an angle of 25 to 35 degrees. In some areas, the railway passes near exposed vertical rock faces up to four or five metres in height (figures 5a and 5b).

19 As a result, the slope on the north side of the railway comprises:

- areas of exposed rock face with *blocks* that could potentially fail and break away from the face (failed blocks seen beside the track were evidence that this had occurred) (figure 6); and, above and between these rock faces,
- areas of soil slope dotted with isolated boulders (figure 7).

Between the areas of exposed rock face adjacent to the railway, the soil slope extends to track level.

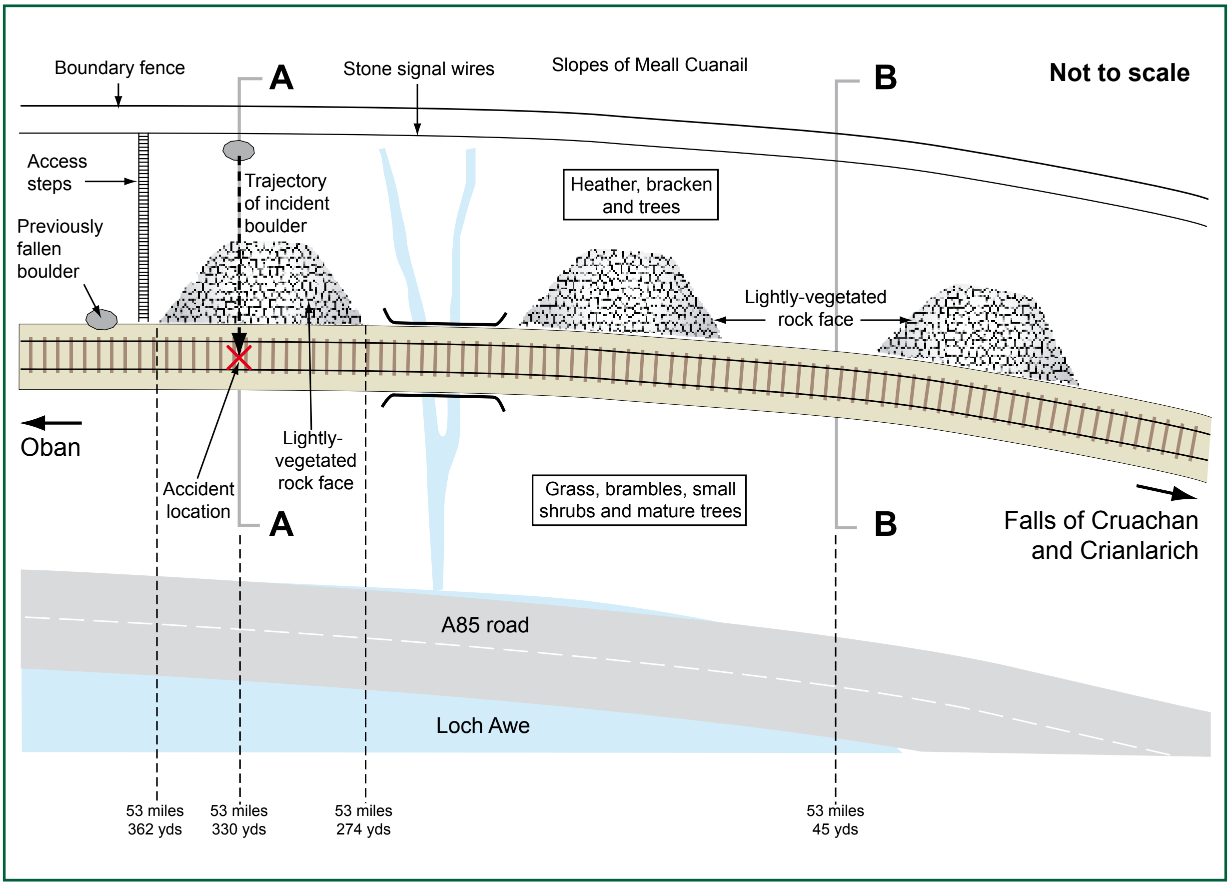


Figure 5a: Plan view of the accident location

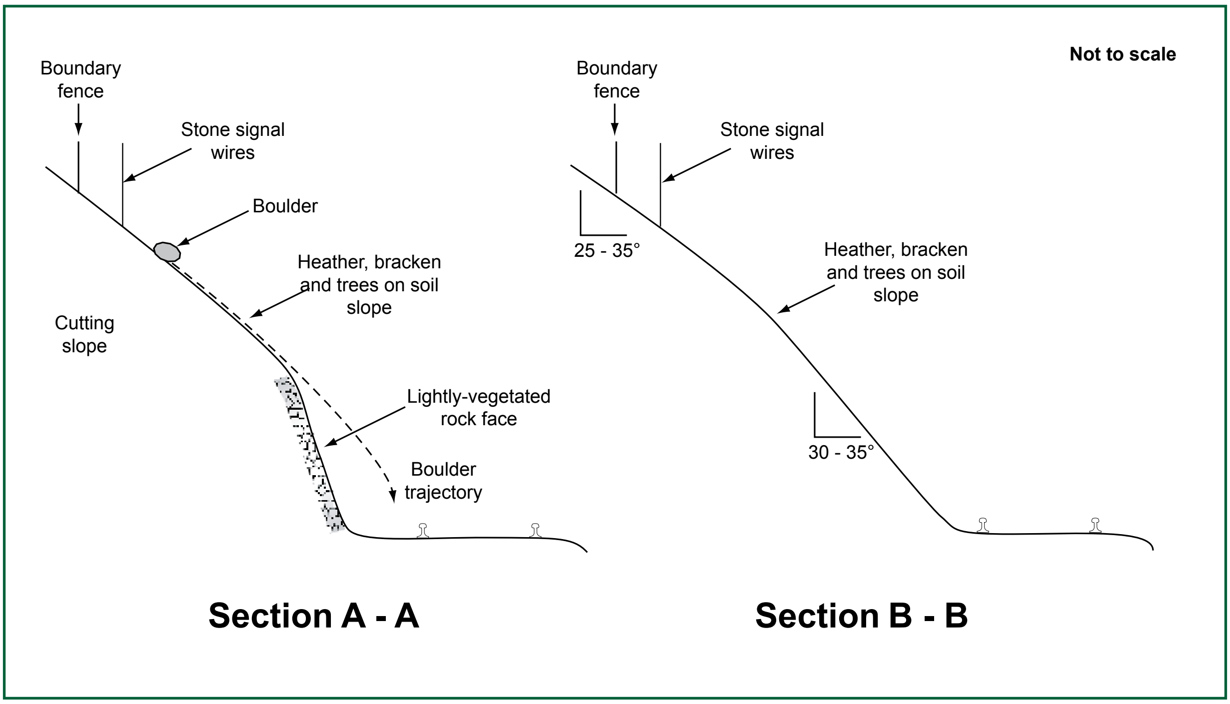


Figure 5b: Profiles of the slope at sections A-A and B-B

Figure 6: Exposed rock face area of the slope showing blocks

Figure 7: Area of soil slope containing isolated boulders (following post-accident de-vegetation) (image courtesy of Network Rail)

20 The areas of soil slope between the northern boundary fence and the railway line and top of the rock faces was covered with a dense growth of heather, bracken and trees, even in winter, when much of it dies back (figure 8).

Figure 8: Winter's view of the slope in the Pass of Brander (image courtesy of Network Rail)

21 Network Rail is responsible for controlling the risk of boulders falling onto the railway, whether it is from within the railway boundary or outside it. Outside the railway boundary, the landowner is primarily responsible for controlling risks that can affect the railway, but Network Rail must also anticipate, so far as it is able to do so, these risks and take appropriate measures. In the case of the Pass of Brander, the risk of rock and boulder fall from outside the railway boundary was recognised by the Caledonian Railway in the 19^{th} century and led to a system of automatic stone signals being installed to control this risk. These signals are still in use.

22 Located just below the railway boundary fence is a vertical screen of ten single strand horizontal steel wires (figure 9). If any of these are broken, semaphore signals either side of the break are automatically replaced to *danger* alerting the driver of an approaching train to a possible blockage ahead (figure 10). In these circumstances, the driver must

- reduce the speed of the train;
- pass the signal at danger;
- proceed cautiously to examine the line; and
- continue at this speed to the second clear signal (because there could be a clear signal between two signals at danger) indicating that it is safe to proceed at normal speed.

The driver must also report the incident to the signaller.

Figure 9: Steel wires that operate the automatic stone signals when broken

Figure 10: One of the automatic stone signals

23 The boulder which derailed the train fell from an area of soil slope above a rock face which was below the vertical screen of horizontal wires. The automatic stone signals therefore could not detect the falling boulder.

The train involved

24 The train involved in the accident is one of a fleet of class 156 diesel multiple units built by Metro-Cammell at their Washwood Heath factory and which first entered service in 1987. Each car is powered by an underfloor-mounted diesel engine which drives both wheelsets of one bogie through a hydraulic transmission and a final drive unit. The maximum speed of a class 156 unit is 75 mph (120 km/h).

25 Class 156 units have a fire suppression system which consists of a heat sensor located above each engine. This automatically activates an extinguisher system when temperatures are greater than 250°C. In addition, there are two hand operated fire extinguishers inside each car.

26 The two cars that make up a unit are semi-permanently coupled together by a *bar coupler*.

27 The RAIB found no evidence that the maintenance, overhaul or driving of the train contributed in any way to the occurrence of the accident.

Events preceding the accident

28 The boulder fell onto the railway during the period of about two hours since the passage of the previous train on the line (running in the opposite direction to the accident train).

29 The accident followed a period of rain, but the amount of rainfall was not exceptional for this area of the Scottish Highlands.

30 The train's journey to the point where the accident occurred was uneventful. It was daylight, but the curvature of the track meant that the driver could not see the boulder in the *four-foot* until he was about 82 metres from it.

31 At this point, the train was travelling at 45 mph (72 km/h), in accordance with the permanent speed restriction in place for passenger trains through the Pass of Brander. As soon as he saw the boulder, the driver shut off power and made an emergency brake application.

32 The driver could do nothing more and the speed of the train had reduced to 40 mph (64 km/h) when it struck the boulder.

Events during the accident

33 On striking the boulder, the train's leading car overrode it and was deflected to the left-hand side down the slope towards the A85 road and Loch Awe below (figure 1).

34 The leading bogie of the trailing car rode onto the boulder (figure 2) and stopped in that position. The trailing bogie of the trailing car remained on the rails. The train travelled about 59 metres after striking the boulder.

35 The bar coupler between the cars and the tree growth supported the leading car and prevented it from falling any further.

36 A flash fire occurred around the engine of the leading car when the boulder seriously damaged the engine *crankcase*. Ignition of fuel/engine oil vapour occurred, but the temperature was insufficient to cause the activation of the fire suppression system. The extent of the fire was insufficient to damage the underfloor of the vehicle and there was therefore no risk to its interior.

37 The wooden sleepers which were under the trailing car when the train stopped probably became coated with oil from the damaged engine of the leading car and were ignited by the brief flash fire.

The consequences of the accident

38 Eight passengers were treated in hospital for minor injuries caused by being thrown around in the leading car when it derailed. There were no injuries in the trailing car.

39 The underframe equipment, including the engine and fuel tank mounted under the leading car, was seriously damaged by the collision with the boulder.

40 Most of the *budget locks* securing the lighting diffusers in the leading car failed to retain the diffusers when the impact with the boulder occurred. This resulted in lighting diffusers swinging down on their hinges either to a point where they were stopped by the wire lanyards used for *secondary retention* (figure 11), or completely in cases where the lanyard also failed. Six lighting diffusers came free from their hinges and fell to the floor. They could have caused serious injury to those on board in view of their weight (5.7 kg each) and sharp edges. However, the RAIB found no evidence that anyone on the train was hit by a detached lighting diffuser. Only three diffusers remained in place. These diffusers had budget locks that were defective and cable ties had been used to secure them.

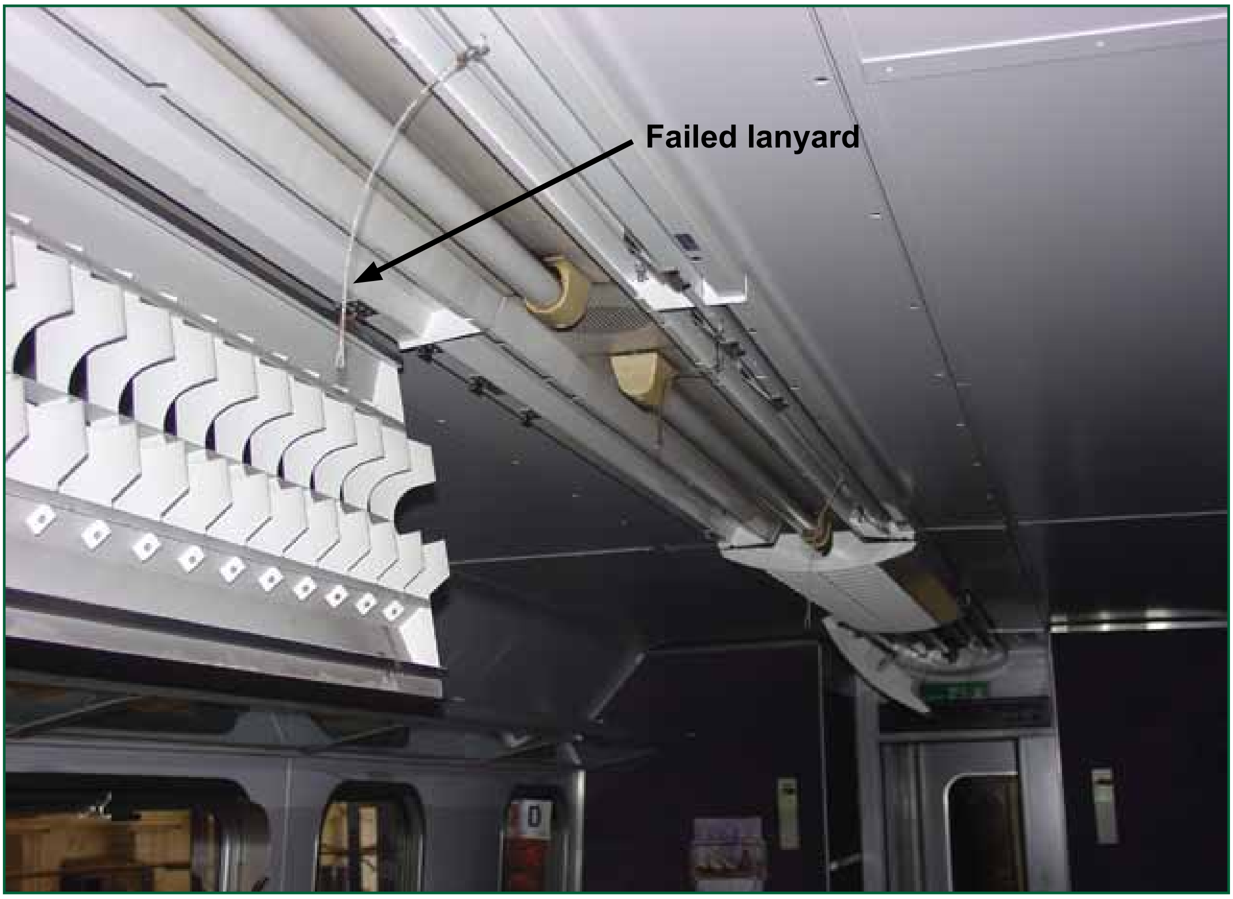


Figure 11: Lighting diffusers hanging down as a result of the collision

41 Minor track damage occurred over approximately a car's length (23 metres).

42 Due to the difficult nature of the recovery operation, the line was not reopened until 06:20 hrs on Monday 14 June 2010. The parallel A85 road was also closed for this period due to the possibility that the leading car could fall onto it, and then because it was required to support the crane used in the recovery of the leading car.

43 The consequences of the accident could have been much worse if the bar coupler and the growth of vegetation had not prevented the leading car from continuing down the embankment and onto the A85 road below.

Events following the accident

44 The conductor and one of the passengers used two fire extinguishers from inside the train to put out the small fire on the burning oil soaked sleepers.

45 The conductor used his company mobile telephone to call the control centre at Banavie and the emergency services. He then assisted the passengers travelling in the rear car to evacuate from it through one of the rear passenger doors.

46 The driver, meanwhile, opened the right-hand leading passenger door of the leading car and, despite the angle of the car, he managed to evacuate the passengers of the leading car through it.

47 The train crew led the passengers from both cars along the track to Falls of Cruachan station, reaching it at 21:35 hrs, where they were met by the emergency services. They were then taken to the Falls of Cruachan power station visitor centre which was specially opened for them. Those passengers who were not hospitalised were taken the remainder of the journey to Oban by bus.

The Investigation

Sources of evidence

48 The following sources of evidence were used:

- witness records of interview;
- data from the *on train data recorder* data;
- site photographs and measurements;
- weather reports and observations at the site;
- examination records of the slope where the accident occurred;
- Network Rail's records relating to the management of earthworks in Scotland;
- records of track inspections carried out;
- records of activations of the automatic stone signal system;
- post-accident reports commissioned by Network Rail, following the limited clearance of vegetation, to investigate the risk of further rock/boulder fall onto the railway;
- Network Rail's standards and guidance; and
- a review of previous RAIB investigations that had relevance to this accident.

Key facts and analysis

Background information

Earthworks management processes

49 The pro-active management of earthworks on the national railway infrastructure is a relatively recent development and the arrangements were not formalised in standards until 1997 when Railtrack[2] standard RT/CE/P/030 'Management of Embankments and Cuttings' was issued. Before then, the approach was to react to observed problems and did not include the routine use of specialist resources to examine earthworks.

50 The management process includes two key activities:

- Regular examination of earthworks by a contractor to visually identify and record any signs of slope instability.
- For an earthwork where concerns are raised over its stability, Network Rail carries out an evaluation to appraise all relevant information, such as the results of examinations and the data from any site investigations, regarding its stability, condition and use, so that it can take an informed decision about what action might need to be taken to ensure safety. An evaluation usually includes a site visit.

51 Since 1997, Railtrack (now Network Rail) standards have required all earthworks more than three metres high, and lower earthworks with known instability, to be examined on a routine basis. The examination interval depends on the condition of the earthwork as determined from the previous examination. If an examination raises concerns about possible slope instability, an evaluation is required to establish how this risk should be managed.

52 Standard RT/CE/P/030 (issue 1), 'Management of Embankments and Cuttings', applied from August 1997. It required embankments and cuttings to be examined and, if appropriate, evaluated. The standard specified the slope features to be examined and the means of reporting the findings. The features included slope geometry; any evidence of instability; the presence and nature of the vegetation on the earthwork, and the effectiveness of drainage systems. Examiners were required to use judgement to categorise each feature using qualitative terms such as 'expected to remain stable', 'appears stable', 'minor defects', 'significant defects' and 'unfit for purpose'. Evaluations were required if any feature was judged to be in the worst category, or if a combination of features gave rise to concern. The intervals between examinations were not specified; they were to be determined from the results of examinations and, where applicable, evaluations.

53 Issue 2 of standard RT/CE/P/030 became effective in December 2002. It extended the scope of issue 1 to include *natural slopes*. The specification for recording of features by examiners was replaced by a requirement to record details in accordance with standard RT/CE/S/065 (issue 1) 'Examination of Earthworks', which was not issued until April 2005. Issue 2 of standard RT/CE/P/030 also introduced specified intervals between examinations based on a slope's condition rating ('serviceable', 'marginal' or 'poor') to be obtained from RT/CE/S/065.

[2] Railtrack was the predecessor body to Network Rail.

54 Issue 1 of standard RT/CE/S/065 was issued with a requirement that it should be applied to all examinations after April 2005. It replaced the judgement based examination process of RT/CE/P/030 (issue 1) with a more precisely specified means of reporting slope features; for example, the size and number of blocks with the potential to fall from a rock face were to be recorded. The new approach was intended to improve consistency between examiners and to allow quantification of the potential for slope instability.

55 Standard RT/CE/S/065 required scores to be allocated to each of the factors observed by the examiner. These scores were then combined to derive a hazard index relating either to a soil slope (the *soil slope hazard index*, SSHI) or to a rock slope (the *rock slope hazard index*, RSHI). The SSHI or RSHI determines both the condition rating of the slope and the interval to the next routine examination of the earthwork (table 1).

Hazard index	Condition rating	Examination interval (years)
SSHI ≥ 10 or RSHI ≥ 100	Poor	One
SSHI 10 – 6 or RSHI 100 -10	Marginal	Five
SSHI ≤ 6 or RSHI ≤ 10	Serviceable	Ten

Table 1: interval between examinations

56 Network Rail standard RT/CE/S/086 ‘Management of Existing Earthworks’ replaced RT/CE/P/030 in June 2005. Although the scope of the document was widened, it did not significantly alter the requirements for routine examinations and evaluations. It was subsequently re-issued as NR/L2/CIV/086 in June 2009, again without significant changes to the examination and evaluation process, although it did introduce instructions relating to the management of vegetation on earthworks where this prevents or impairs their examination.

57 Network Rail guidance note NR/GN/CIV/203 ‘Evaluation and Assessment of Earthworks’ was issued in October 2007 and stated that, where an examination could not be completed, ‘the risks associated with the shortage of information on the condition of the earthwork should be reviewed’.

58 Network Rail standard NR/L3/CIV/065 (issue 2) replaced RT/CE/S/065 (issue 1) as the standard to be applied to all examinations undertaken after 1 April 2009. Changes introduced included reinforcing NR/GN/CIV/203 by requiring that ‘a risk assessment shall be completed where an examination is incomplete; for example, where access was restricted’. In such circumstances, the earthworks manager is responsible for identifying and then implementing any necessary mitigation measures.

59 Standard RT/CE/S/086 (June 2005) required an evaluation to be carried out where the examination of an earthwork classified it as poor for the first time, or where further deterioration has occurred of an earthwork previously classified as poor. It did not did not prescribe how the evaluation should be carried out.

60 Standard NR/L2/CIV/086 covers the actions arising from an evaluation. They include stripping vegetation to allow a full examination of the slope in cases where vegetation growth has prevented this; implementing urgent or long term physical works when the stability of the earthwork may be in doubt; or, most commonly, carrying out examinations at an annual frequency with the intention of detecting any further deterioration of the earthwork and taking appropriate action before failure occurs.

61 The roles required to implement the examination and evaluation process were described in standard RT/CE/S/065. This required that an appointed earthworks manager 'should ensure that earthworks remain fit and safe for use'. The earthworks manager was responsible for the appointment of one or more earthworks examining engineers who were responsible for appointing earthwork examiners.

62 The earthworks manager, earthworks examining engineer and earthworks examiner are required to meet the competence standards specified in Network Rail standard NR/SP/CTM/017 'Competence & Training in Civil Engineering', published in June 2006. The route geotechnical engineer must meet the earthworks manager competency.

Management of the slope where the accident occurred

63 Network Rail's Scotland Route geotechnical team, based in Glasgow, was responsible for monitoring the earthworks examination process carried out by contractors; carrying out evaluations; and proposing earthworks for remedial action where measures were required to ensure continuing safety. The team was led by the route geotechnical engineer, Scotland, who had carried out that role since 2003, supported by senior earthworks management engineers and an earthworks assessment engineer.

64 Network Rail assessed the competence of the senior earthworks management engineer, whose responsibilities included the Pass of Brander area, and the earthworks assessment engineer in April 2009. The assessment was to the specific competence standards concerning earthworks in standard NR/SP/CTM/017 and was valid for two years. They were deemed to be 'competent and experienced'.

65 A contractor was appointed to carry out examinations of earthworks in Scotland from 2003 to 2009 (a new contractor was appointed from May 2009). The contractor employed earthworks examiners to carry out the examinations in the Pass of Brander and an earthworks examining engineer, who reviewed the examination reports. Both the examiner who carried out the last examination before the accident, and the earthworks examining engineer who reviewed the reports, were subject to the contractor's competence management system demonstrating compliance with standard NR/SP/CTM/017 (paragraph 62). Their competence records were in order when the accident occurred.

66 The contractor carried out the first examination in the Pass of Brander between 52 miles 1594 yards and 53 miles 455 yards on 2 March 2005. This included the location of the accident (53 miles 330 yards). This examination was carried out from the air (permitted by the standards at the time), by helicopter, whereas subsequent examinations were carried out on foot from track level.

67 Issue 2 of standard RT/CE/P/030 (paragraph 53) was not implemented in Scotland until 2003, when the first contractor to carry out routine examinations of Scottish earthworks was appointed. Although RT/CE/S/065 was not issued until April 2005, Network Rail agreed with the contractor that it should work to the draft version of this standard. This was already available when the contractor carried out the examination on 2 March 2005.

68 Although standard RT/CE/S/065 stated it should be applied from April 2005, the April 2006 examination at the accident site did not calculate the RSHI and SSHI values required by the standard. This was because, at that time, the algorithms to calculate these hazard indices were still in development. The condition rating for this examination was therefore based on the contractor's professional judgement (as it was for the previous examination on 2 March 2005).

69 Subsequent examinations at this site were carried out to standard RT/CE/S/065 and condition ratings based on the RSHI and SSHI values were obtained (the results of the examinations are summarised later in the report in table 2). With Network Rail's agreement, the examination contractor continued to allocate a condition rating based on its professional judgement. At the accident site, Network Rail used the rating based on the contractor's professional judgement to determine the interval to the next examination, rather than the rating derived from the hazard indices.

70 Until 2009, the findings of each examination were recorded in an earthwork examination report which the examiner could complete in freehand. Each report was signed off by the examiner and approved by the earthworks examining engineer. After 2009, a new recording system using a hand held computer, GISmo (Geographical Information System – mobile), was introduced so that the results of examinations could be uploaded to a Network Rail database. This did not change the method of carrying out examinations, but the method of recording examinations changed, and the facility to allow the examination contractor to allocate a condition rating based on judgement was removed.

71 Under the new system, examination reports are based on maximum five chain[3] lengths along an earthwork and are produced from input data recorded by the examiner on a hand held computer. The input data is mainly created from drop down menus with only limited ability to record free text.

72 After the re-issue of standard RT/CE/S/065 as NR/L3/CIV/065 in December 2008 (implementation date of April 2009), where a cutting is formed through a mixture of rock and soil, condition ratings for both the soil and rock slopes are required to be determined from the SSHI and the RSHI if both materials are more than three metres thick (ie vertical height). Where the thickness of rock or soil is less than three metres, but the height of the cutting is more than three metres, a condition rating (from the SSHI or RSHI) is only required to be determined for the predominant material type in the cutting.

73 Application of the new issue of standard NR/L3/CIV/065 to the accident location resulted in only the RSHI being calculated at the examination on 21 April 2009, the last one before the accident.

74 A further examination would have taken place in late 2009 or early 2010 if, as had happened until April 2009, the examination cycle was based on the earthwork being in a poor condition. The earthwork was subsequently managed as being in a marginal or serviceable condition, and therefore needing five or ten yearly examinations, after April 2009 for reasons explained in paragraph 113.

75 The comments on all the examination reports of the earthwork at the accident site refer to the rock face areas of the slope, with no comments about the soil areas of the slope. The boulder that derailed the train fell from the soil slope area between the boundary fence and the top of a rock face.

[3] One chain is 22 yards (20.12 metres).

76 Close to the accident site, the soil slope below the railway boundary fence extends right down to the railway and is the same in character as the soil slope between the rock face and the boundary fence. Post accident investigations close to the accident site found loose boulders on the areas of soil slope after the partial removal of vegetation.

77 A photograph in the examination report dated 11 February 2007 shows a boulder in the *cess* which was not reported by the examiner. The boulder had apparently fallen from a soil slope and was still present when the accident occurred (figure 12).

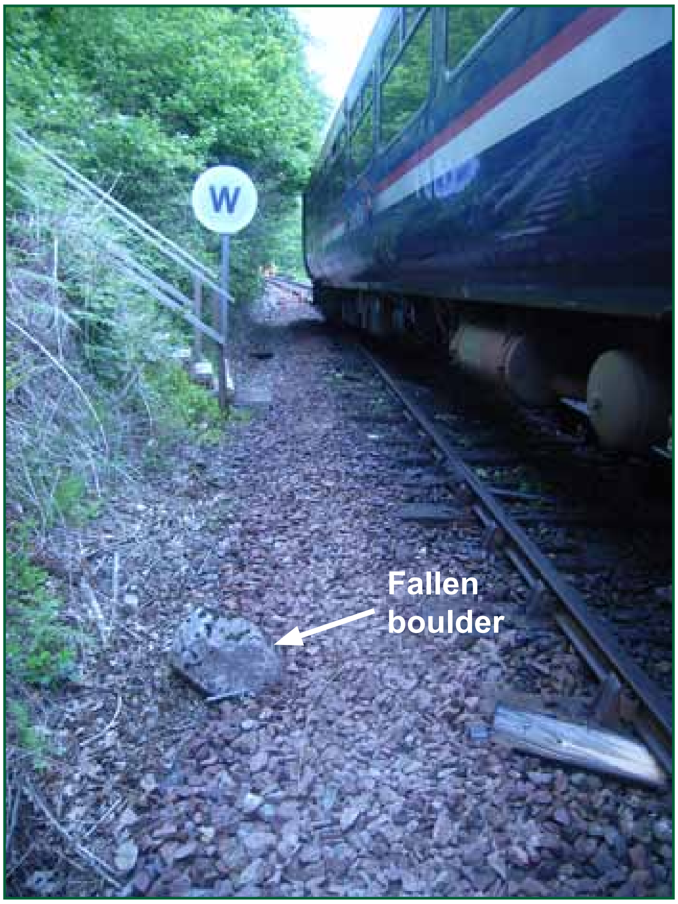


Figure 12: Previous fallen boulder from the soil slope

78 The results of the examinations carried out up until the accident are presented in table 2. This differentiates between:

- the combined rock face and soil slope between 53 miles 274 yards and 53 miles 362 yards, a length that includes the location of the accident at 53 miles 330 yards (figure 5, section A-A); and
- the area immediately west of this, beyond 53 miles 362 yards, where the soil slope reaches track level.

The table includes condition ratings obtained from the professional judgement of the examination contractor, based on their site observations, and from the SSHI and RSHI, where calculated (see table 1). The following should be noted:

- A single SSHI value covers soil slopes above rock faces and neighbouring soil slopes extending to track level.

- The examination contractor noted on the reports of the examinations on 11 February 2007 and 13 November 2007 that 'the SSHI and RSHI scores and condition ratings are calculated from Network Rail algorithms and are not warranted by the Engineer'. Witness evidence suggests that Network Rail's Scotland geotechnical team accepted, and acted upon, the condition ratings based on professional judgement, rather than the ratings calculated from the RSHI and SSHI.
- 'Poor/marginal vegetated' is a rating that was not included in standard RT/CE/S/065 but was agreed between Network Rail Scotland and the contractor to deal with slopes where the extent of vegetation growth prevented examiners determining whether the slope was in a poor or marginal condition. Network Rail managed such slopes on the assumption that they were poor.
- Examinations should be carried out during the part of the year when the vegetation has died back in order to improve the opportunities for visual inspection.

<table>
<tr><th rowspan="2">Examination Date and method</th><th colspan="2">Condition rating</th><th colspan="2">Examination status[4]</th></tr>
<tr><th>Combined rock face & soil slope at accident site</th><th>Soil slope reaching track level near accident site</th><th>Rock faces</th><th>Soil slopes</th></tr>
<tr><td>2 March 2005 aerial, manually recorded</td><td>Poor (judgement)</td><td>Marginal (judgement)</td><td>Incomplete due to vegetation cover</td><td>Complete</td></tr>
<tr><td>26 April 2006 on foot, manually recorded</td><td>Poor (judgement)</td><td>Marginal (judgement)</td><td>Incomplete due to vegetation cover</td><td>Complete</td></tr>
<tr><td rowspan="2">11 February 2007 on foot, manually recorded</td><td>Poor/Marginal Vegetated (judgement)</td><td>Marginal (judgement)</td><td rowspan="2">Incomplete due to vegetation cover</td><td rowspan="2">Complete</td></tr>
<tr><td colspan="2">Rock face serviceable (from RSHI)
Soil slope marginal (from SSHI)</td></tr>
<tr><td rowspan="2">13 November 2007 on foot, manually recorded</td><td>Poor/Marginal Vegetated (judgement)</td><td>Marginal (judgement)</td><td rowspan="2">Incomplete due to vegetation cover</td><td rowspan="2">Complete</td></tr>
<tr><td colspan="2">Rock face serviceable (from RSHI)
Soil slope serviceable (from SSHI)</td></tr>
<tr><td rowspan="2">21 April 2009 on foot, GISmo record</td><td colspan="2">Rating based on judgement not requested by GISmo and not reported</td><td colspan="2">Incomplete</td></tr>
<tr><td colspan="2">Rock face marginal from 274 yards to 330 yards and serviceable from 330 yards to 362 yards (from RSHI)

Soil slope data not requested by GISmo and not reported</td><td>Rock face reported as 'too much vegetation to inspect fully'</td><td>Soil slope data not requested by GISmo and not reported</td></tr>
</table>

Table 2: Earthwork examinations carried out where the accident occurred

[4] The examination process requires incomplete examinations to be reported. In the absence of a report, the examination is considered by Network Rail to be complete.

79 Following the first examination on 2 March 2005, and in response to poor condition ratings, Network Rail's geotechnical staff visited the Pass of Brander early in February 2006 to carry out an evaluation. They focussed most of their attention on the rock face areas where potential failures were most obvious and which they perceived to be of the greatest risk to the operational railway.

80 The RAIB found no evidence that the evaluation was reviewed following the issue of guidance NR/GN/CIV/203 (paragraph 57). This stated that the risk associated with the shortage of information on the condition of the earthwork (caused by vegetation in this case) should be reviewed. However, given that the examination reports referred to incomplete examinations caused by vegetation in respect of the rock faces, it is likely that any review would have considered the rock faces and not the soil slope.

81 Witness evidence was that inherent within the evaluation process carried out was a consideration of the risks to the operational railway. The RAIB has not been able to establish whether, or to what extent, this included any risks arising from the soil slope. There was nothing in the examination reports to alert Network Rail to the incomplete soil slope examinations, or the potential risks from the soil slope.

82 As a result of the evaluation in 2006, Network Rail decided that the rock face areas should be de-vegetated, *scaled* and netted to prevent further rock falls. The process for determining whether work is carried out includes the use of an Earthworks Prioritisation Model.

83 The Earthworks Prioritisation Model is a quantitative tool to rank business plan items. It considers various factors that include the condition of the earthwork, traffic density, line speed, track configuration and type of rolling stock to give a numerical value. All work in the five year business plan is entered at the discretion of the route geotechnical engineer, but if the value from the Earthworks Prioritisation Model is above 500, the works may be included in the business plan without further justification. If the value from the Earthworks Prioritisation Model is below 500, remedial works may only be included in the business plan if Network Rail's geotechnical staff consider that the Earthworks Prioritisation Model has not adequately reflected the site conditions.

84 The Earthworks Prioritisation Model score for the accident site was 333.3, but the Network Rail geotechnical team believed the works needed doing and made the necessary justification to include them in the business plan. De-vegetation and scaling was planned for 2010 to 2012 and installation of the netting for 2012/13.

85 The remediation work at the accident site was part of a package of work to carry out rockfall protection works throughout the Pass of Brander for completion in 2012/13. This follows rockfall protection works already completed in 2007/08 in part of the Pass of Brander and de-vegetation work at other sites in the Pass of Brander completed in 2007/08 and 2008/09. Remediation work had also been completed and was planned elsewhere between Crianlarich and Oban.

86 The requirement to review risks due to incomplete examinations was introduced in October 2007 by guidance note NR/GN/CIV/203 (paragraph 57). This had not been issued when Network Rail evaluated the accident site in 2006. Incomplete examinations due to vegetation on soil slopes were not reported in the examination reports so there was nothing to trigger a review of the associated risks after NR/GN/CIV/203 became effective.

87 Separate from the earthworks management processes was a two-weekly inspection of the track on the Oban line, including through the Pass of Brander, by Network Rail's track inspection staff. The RAIB reviewed the records of the inspections and found no reports pertaining to the earthworks in the vicinity of Falls of Cruachan. There was witness evidence that there was telephone contact, typically weekly, between the manager of the track inspection staff and Network Rail's earthworks staff. This provided an opportunity for concerns to be shared, such as the occurrence of any rock or boulder falls (which may also have been reported direct to the route control).

Previous occurrences of a similar character

88 In August 1946 the 06:05 hrs train from Oban to Glasgow hit a large boulder in the Pass of Brander. Few details are available: the steam locomotive hauling the train rode over the boulder and derailed, along with several carriages. Nobody was hurt in the accident.

89 On 5 May 1997, the 18:10 hrs train from Oban to Glasgow Queen Street, consisting of a class 156 diesel multiple unit, struck a landslip just east of Falls of Cruachan between 52¼ and 52½ miles. The train was completely derailed but remained upright and there were no serious injuries to passengers or crew. The landslip material, consisting of glacial debris and soil, fell from below the wires operating the automatic stone signals (which were therefore not triggered). It followed a period of exceptionally wet weather.

90 On 11 October 2005 on the West Highland line between Tulloch and Corrour, a freight train struck a large boulder that had fallen onto the track. The train was not derailed, but the locomotive was damaged to the extent that it could not work forward. The boulder, which was of the same size as the one that fell onto the track near Falls of Cruachan, had fallen down the adjacent hillside onto the railway. There was no system equivalent to the automatic stone signals fitted in the Pass of Brander.

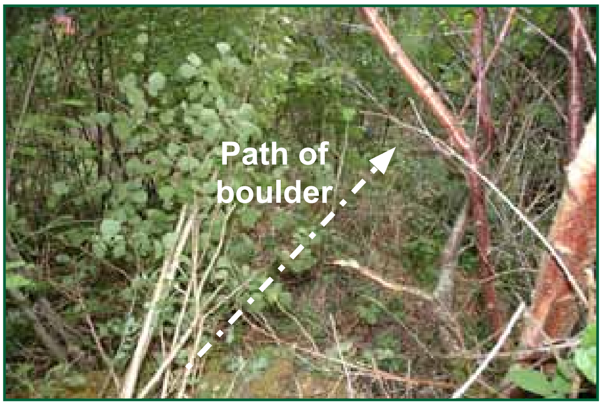
91 The RAIB examined the records of stone signal activations in the Pass of Brander over a four year period to the end of 2010. None were caused by falling rocks or boulders. Most activations were reported as having been caused by animals, such as deer, and by adjacent vegetation, such as tree branches.

Identification of the immediate cause[5]

92 **The immediate cause of the accident was that a boulder, within the railway boundary, became dislodged from the cutting slope on the north side of the railway and fell into the four-foot. The train struck the boulder causing it to derail.**

93 Inspection of the site after the accident identified the original location of the boulder and its path onto the railway (figures 13a and 13b).

[5] The condition, event or behaviour that directly resulted in the occurrence.



Figures 13a and 13b: Initial position of and subsequent path of the boulder onto the railway

94 Marks were evident on the running rail adjacent to the cutting side. It showed that the boulder had rolled over it before coming to rest in the four-foot.

95 The movement of the boulder onto the track was not detected because it fell from within the railway boundary, and below the wires which operate the system of automatic stone signals. This system had been installed to mitigate the risk of boulders falling from outside the railway boundary.

Identification of causal factors[6]

Why the boulder became dislodged

96 **The boulder became dislodged through natural processes that included root jacking and soil erosion. This was a causal factor.**

97 The boulder had been located in a socket surrounded by soil and tree roots and its path onto the railway track was apparent from damage to vegetation. The RAIB observed on site that the socket was surrounded by tree roots positioned in a manner likely to have prised the boulder from its socket; a process that would have been exacerbated by erosion of the surrounding soil through normal rain fall. The potential for root jacking to cause instability on the soil slopes was not identified as a risk because of shortcomings in the examination and evaluation system (described in paragraphs 98 to 115).

Earthwork examination and evaluation

Identification of the boulder hazard

98 **The examination and evaluation system did not identify the boulder hazard on the soil slope between the top of the rock face and the railway boundary. This is a possible causal factor because even if the boulder hazard had been identified, the accident would only have been prevented if appropriate remedial work had been implemented before the accident occurred.**

[6] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

99 The non-identification of the boulder hazard occurred due to a combination of the following factors:

- neither the examiners nor those who carried out the evaluation could adequately inspect the slope due to vegetation cover and access constraints;
- the examination contractor submitted examination reports for the soil slope which did not record that examinations were incomplete;
- Network Rail's Scotland Route geotechnical staff did not query reports from the examination contractor which did not fully describe the extent to which examinations were incomplete;
- Network Rail's Scotland Route geotechnical staff saw vegetation on the soil slope when they carried out the evaluation in February 2006 but did not arrange for sufficient of it to be removed to allow a complete evaluation.
- the examiners did not appreciate the warning given by a boulder which could have fallen from a soil slope within the railway boundary during, or before 2007;
- the examiners and those who carried out the evaluation probably concentrated on the more obvious rock face risks rather than the soil slope risks within the railway boundary;
- following the examination of 21 April 2009, no further examination was carried out before the accident occurred; and
- the system of automatic stone signals (paragraph 21) possibly led to a belief that there was adequate protection against the risk of boulders falling from the soil slope.

The above factors are discussed more fully in the following paragraphs.

Vegetation cover and access constraints

100 The soil slope was covered by a dense growth of moss, heather, bracken and trees. This concealed isolated boulders, even when the vegetation died back in winter (figure 8).

101 The growth of vegetation at and close to the accident site was not just confined to the earthwork at this location but extended through much of the Pass of Brander. The RAIB obtained evidence that slopes adjacent to other railways in Scotland, which are part of Network Rail's managed infrastructure, are similarly affected by vegetation growth to the extent that it impairs their proper examination.

102 The soil slope at the accident site was steep which made it difficult, and potentially dangerous, to access. It would have been unsafe for examiners to climb the slope as they normally worked alone. Standard RT/CE/S/065 requires a physical examination of slopes but recognises that this may not always be practical where slopes are too steep to traverse, or access is unsafe. It states that where access is difficult, consideration may be given to using aerial photography. The first examination on 2 March 2005 was carried out by aerial means (paragraph 66), but boulders on the slope were concealed by vegetation and could not be seen from the air.

103 Post-accident vegetation clearance close to the accident site revealed a significant number of boulders on the soil slope within the railway boundary, including some which were removed immediately as they posed a threat to railway safety. The combination of vegetation cover and poor access prevented examiners, and those who carried out the evaluation, seeing the boulder that caused the accident, or other loose boulders which should have alerted them to soil slope risks.

Incomplete examination reports

104 Standard RT/CE/S/065 required examiners to report problems during an examination, which included vegetation obscuring slopes and access difficulties. However, reports from the examination contractor did not state that the examination of the soil slope was incomplete, nor did they refer to the vegetation which obscured the slope and prevented hazards such as loose boulders being identified (table 2).

105 If an examination report did not report that the soil slope examination was incomplete, or there was vegetation obscuring the slope, Network Rail could reasonably assume that the examination was complete. However, Network Rail's Scotland Route geotechnical staff had undertaken an evaluation of the slopes in the Pass of Brander in February 2006 (paragraph 79) and should therefore have been aware that the soil slope was obscured by vegetation. The RAIB has not been able to establish why Network Rail did not query the examination reports even though they did not state that the examinations of the soil slope were incomplete.

106 The RAIB has not found any evidence that the risk arising from an incomplete examination of the soil slope at the accident site was ever considered.

107 If reports of an incomplete examination of the soil slope had been made, it may have triggered a more detailed consideration of the risk arising from the slopes in the area, and therefore appreciation of the associated boulder hazard.

Vegetation not removed to allow complete examination and evaluation

108 When Network Rail's Scotland Route geotechnical staff visited the Pass of Brander in 2006 to carry out the evaluation, they did not consider stripping any of the vegetation on the soil slope back to allow a full examination of its condition.

109 The soil slope above the rock faces and those extending to rail level are of similar character. Information obtained by examining the soil slopes reaching the railway could have provided a warning of a possible risk from the slope above the rock faces.

No appreciation of the warning given by a nearby boulder which could have fallen from the soil slope during, or before, 2007

110 A photograph taken during the examination on 11 February 2007 shows another boulder in the cess, about 20 metres west of the location where the boulder that derailed the train fell. This earlier boulder could have fallen from below the wires that trip the automatic stone signals (it is unlikely to have fallen from above these wires as its relatively small size means that it would probably have been stopped by the railway boundary fence or by the vegetation outside this fence). The boulder was still present when the accident occurred (figure 12). It was not identified in the 2007, or any subsequent examination report, presumably because the examiners did not appreciate that it was a possible warning of the risk from loose boulders on the soil slope.

Concentration on the rock face risks rather than the soil slope risks

111 The evidence from examination reports and witness testimony is that staff who carried out the examinations and the evaluation perceived the areas of rock face to be the main risk. Much of these were visible and there was evidence of potential failure occurring from the rock areas (eg due to root jacking) and blocks in the cess that had broken off areas of rock face. By contrast, apart from the possible warning from the boulder in the cess, there was no visible evidence of any threat to the railway from dislodged boulders on the soil areas of the slope.

112 The perception that the areas of rock face were the main risk is likely to have resulted in the incomplete examinations of the soil slope not being reported; the acceptance by Network Rail of the reports; the absence of any risk assessment of the soil slope; and an absence of action to remove any vegetation from the soil slope to identify its true nature.

No examination carried out after April 2009

113 Shortly after the examination of 21 April 2009, the examination contract changed and a new examination contractor was appointed. Based on the RSHI, Network Rail advised the new contractor that the condition ratings for the slope where the accident occurred were marginal for the slope just before where the accident occurred and serviceable for the slope just after it (table 2). The new contractor therefore took the interval to the next examination to be five years and ten years respectively (table 1). No account was therefore taken of the previous ratings based on professional judgement, and accepted by Network Rail, which led to examinations carried out at an annual frequency (there is further discussion of condition ratings and the RSHI in paragraphs 127 to 133).

114 Based on an annual frequency, it is likely that the new contractor would have carried out an examination towards the end of 2009, or early in 2010 (ie during the period when the vegetation has died back), and therefore before the accident occurred. It is not known what effect (if any) this would have had on the occurrence of the accident, but it is possible that the new contractor would have reported that vegetation clearance was required in order to complete an examination of the soil slope. This would have prompted Network Rail to assess the risk associated with incomplete examination of the soil slope, as required by standard NR/CIV/L3/065, and may have resulted in the proposed remediation work being brought forward. Although unlikely, therefore, an examination by the new contractor could have resulted in measures which would have prevented the accident.

The automatic stone signals

115 Although the RAIB has no direct evidence, it is possible that the system of automatic stone signals led to a belief that the boulder hazard within the railway boundary was controlled. The rationale for the detection wires close to the railway boundary is unknown, but it is assumed to be because the risk of falling boulders from outside the railway boundary was recognised. The risk from within the boundary might have been unrecognised, considered acceptable or managed concurrently with the vegetation control needed to minimise the risk of lineside fires ignited by steam locomotives. Such maintenance would have stopped during the 1960s when regular steam traction was withdrawn.

Remedial works

The planning of remedial works to reduce identified risks

116 **The boulder fell onto the railway before planned de-vegetation and scaling works were carried out. Remedial works were planned, but had not been started, at the accident site because a higher priority had been given to other sites where the risks had been assessed to be greater. The planned remedial works were targeted at the adjacent rock face below the initial location of the fallen boulder but would probably have been extended to cover this after the works started. The prioritisation of remedial works is therefore a probable causal factor[7].**

117 Reports from examiners, and the results of Network Rail's evaluation in 2006, gave rise to remedial works being planned to reduce the risk arising from the rock face areas of the earthwork (paragraph 82). These included exposing areas of soil slope at the top of the rock face to provide fixings for the rock face netting.

118 The area of soil slope above the rock face to be exposed as part of the remedial works was initially planned to be just sufficient to be able to secure the netting over the rock face. This would not have been enough to reveal the boulder that caused the accident. However, based on witness evidence, and remedial works done elsewhere in Scotland, for instance on the line from Dingwall to Kyle of Lochalsh, it is likely that if the initial vegetation clearance to secure the netting over the rock face had exposed unsecure boulders, the extent of de-vegetation and scaling would have been increased to encompass the whole of the soil slope above the rock face that was within the railway's boundary.

119 Although the works were in the business plan, they were prioritised along with other remedial works planned throughout Scotland and the de-vegetation and scaling was not due to be completed until between 2010 and 2012 (paragraph 84). If the remedial works had been executed sooner, the accident would probably have been prevented.

[7] Estimated >75% probability of the accident being avoided. The quantity and quality of evidence is good but there remains some residual uncertainly.

Observations[8]

The Earthworks Prioritisation Model

120 Network Rail prioritises earthwork remedial schemes using the Earthworks Prioritisation Model and professional judgement (paragraph 83); this combination of activities is described in this report as the earthworks prioritisation process. The accurate prediction of earthwork failures requires a detailed knowledge of sub-surface ground conditions (rather than the general indication available from examination of exposed surfaces); precise analytical methods; and knowledge of variables such as future weather conditions and future changes to vegetation. Since these are often unavailable, the Earthworks Prioritisation Model uses observations of current slope condition as indicators of future slope behaviour. The prediction is based on experience gained through observing the performance of other slopes.

121 The RAIB obtained an indication of the reliability of Network Rail's earthworks prioritisation process, as applied to rock falls, by comparing sites of actual rock falls with the sites which Network Rail had already identified as being of greatest concern. These are taken to be the locations included in Network Rail's business plan as requiring remedial work by March 2014. This is only an indicator of earthwork prediction reliability because the consequences of an earthwork failure also affect whether a site is included in the business plan.

122 The RAIB reviewed the failures of earthworks managed by Network Rail in Scotland for the period from April 2006 to January 2011 when there were 12 failures, six of which occurred before April 2009. Of these six, no remedial works were planned before failure occurred. Of the remaining six failures that occurred after April 2009, Network Rail had planned to carry out remedial works at four of the locations before the failures occurred, although in the case of the Falls of Cruachan failure, the remedial works that were planned related to the rock faces rather than the boulder hazard.

123 Both the Earthworks Prioritisation Model and the professional judgement used in the earthworks prioritisation process depend on previous experience. It is likely that their reliability can be improved by taking account of further experience as this becomes available. They should therefore be reviewed periodically and, if necessary, modified in the light of experience. This review should take account of the extent to which vegetation may be directly affecting slope stability and the extent to which vegetation prevents the full examination, or full evaluation, of a slope.

The condition rating of slopes comprising mixed ground determined from the SSHI or the RSHI

124 Network Rail standard NR/L3/CIV/065, in force since 1 April 2009, requires that where a cutting more than three metres high is formed through a mixture of rock and soil, and the thickness of the rock or soil is less than three metres, a condition rating shall be determined using SSHI or RSHI (but not both) for the predominant material type in the cutting (paragraph 72). The standard requires a condition rating from both SSHI and RSHI if both soil and rock are more than three metres thick.

[8] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

125 It is possible that the predominant material type might not be the constituent of the slope of highest risk resulting in Network Rail having an incomplete appreciation of a slope's overall condition. The highest risk would be identified reliably if both material types were scored separately.

126 At Falls of Cruachan, compliance with standard NR/L3/CIV/065 resulted in a condition rating for the soil slope not being determined from the SSHI in the last examination before the accident occurred. This was because the rock slope was deemed to be the predominant material.

Condition ratings and the RSHI

127 Until April 2006, examiners reported slope condition ratings at Falls of Cruachan based only on the examining contractor's professional judgement. Two sets of ratings were reported for the February 2007 and November 2007 examinations; one set was based on the contractor's engineering judgement and the other set was derived from the SSHI and RSHI. The ratings based on judgement generally indicated a less satisfactory slope than the ratings from the hazard indices. The differences were greatest for rock slopes where the RSHI always gave marginal or serviceable ratings, never the poor or poor/marginal vegetated assigned by judgement (table 2). Network Rail's intention to carry out remedial works (paragraph 117) shows that, in the professional opinion of their geotechnical engineers, the slope condition was poor.

128 The April 2009 examination was the first to use the GISmo system. This system automatically generated rock slope conditions of serviceable and marginal based entirely on the RSHI (table 2). GISmo did not allow the examiner to modify the automatically generated slope condition rating although there are opportunities for examiners to make comments within the body of the GISmo report. These opportunities include a supplementary scoring system called 'rate risk' which is related to the trend of the rate of deterioration and gave a 'risk category' of marginal for rock faces examined in April 2009. It is unclear how this risk category relates to the condition rating but it did not reflect the judgement of professional staff that the rock slope was in poor condition.

129 Witness evidence from the examination contractor's staff was that they were concerned the RSHI, adapted from a system used in the quarry industry, did not result in a true condition rating of railway cutting slopes. In addition to the slope at Falls of Cruachan, there had been other examples of slopes being calculated as serviceable from the hazard index, but the examining engineers rated them as poor. The examination contractor and Network Rail were aware of this and Network Rail was discussing the issue at the regular national meetings of the earthworks assessment engineers (who are part of the route geotechnical teams – paragraph 63).

130 If the accident slope had been managed only on the basis of examination reports produced using the GISmo system, it is unlikely to have been recognised as an area of concern. This is because Network Rail standards generally only require examination reports to be reviewed if the condition rating is given as poor[9]. Network Rail's geotechnical staff were managing the cutting slope on the basis that it was in poor condition because these staff were very familiar with the rock slope problems in the Pass of Brander. This familiarity is unlikely to exist at all other sites where the RSHI gives unrealistic condition ratings.

[9] Approximately 1% of examination reports with "marginal" and "satisfactory" outcomes are reviewed by Network Rail for quality control purposes.

131 Although vegetation characteristics are recorded during examinations, the potential for boulders being loosened by root jacking is not explicitly scored as an input to the SSHI or the RSHI. This means root jacking will not be reflected in condition ratings derived from these indices. The risks associated with root jacking on the rock face were appreciated during examinations at the accident site – the November 2007 examination report included a photograph of the rock face annotated to show a root with the potential to cause instability. It is likely that this was a factor considered when the examiner used their professional judgement to give the rock slope a poor/marginal vegetated rating. Root jacking was not identified on the soil slopes due to shortcomings in the examination and evaluation of these areas (paragraph 98).

132 The single boulder in the cess at the foot of the soil slope near the accident site was indicative of possible loose boulders below the stone signal detection wires (paragraph 110). Depending on the scores allocated to other aspects of a soil slope, it is possible that examination of a slope with loose boulders may not generate a SSHI sufficient to result in a poor condition rating, even if, in the examiner's professional opinion, the risk from boulders is sufficient to justify a poor rating.

133 Relying only on the condition ratings currently produced by GISmo using RSHI and SSHI could give Network Rail an incorrect impression about the condition of its slopes and lead to inappropriate subsequent actions. This occurred at Falls of Cruachan following the change of contractor in 2009 and led to no examination being carried out after April 2009 (paragraph 113).

Security of lighting diffusers as the train derailed

134 Passengers could have been injured by falling lighting diffusers in the saloon of the leading car. This occurred when the budget locks, used to secure the diffusers, and the secondary retention lanyards failed to prevent the diffusers swinging down and subsequently becoming detached from their hinges (paragraph 40).

Summary of Conclusions

Immediate cause

135 The immediate cause of the accident was that a boulder, within the railway boundary, became dislodged from the cutting slope on the north side of the railway and fell into the four-foot. The train struck the boulder causing it to derail. (**paragraph 92**).

Causal factors

136 The causal factor was:

- the boulder became dislodged through natural processes that included root jacking and soil erosion (paragraph 96).

137 It is possible that the following factor was causal:

- the examination and evaluation system did not identify the boulder hazard on the soil slope between the rock face and the railway boundary (**paragraph 98, Recommendations 1, 2 and 3**).

This occurred due to a combination of the following factors:

a. neither the examiners nor those who carried out the evaluation could adequately inspect the slope due to vegetation cover and access constraints (paragraphs 100 to 103);

b. the examination contractor submitted examination reports for the soil slope which did not record that examinations were incomplete (paragraph 104 to 107);

c. Network Rail's Scotland Route geotechnical staff did not query reports from the examination contractor which did not fully describe the extent to which examinations were incomplete (paragraphs 104 to 107);

d. Network Rail's Scotland Route geotechnical staff saw vegetation on the soil slope when they carried out the evaluation in February 2006 but did not arrange for sufficient of it to be removed to allow a complete evaluation (paragraphs 108 and 109);

e. the examiners did not appreciate the warning given by a boulder which could have fallen from a soil slope during, or before, 2007 (paragraph 110);

f. the examiners and those who carried out the evaluation probably concentrated on the more obvious rock face risks rather than the soil slope risks (paragraph 111 to 112);

g. following the examination of 21 April 2009, no further examination was carried out before the accident occurred (paragraph 113 to 114); and

h. the system of automatic stone signals possibly led to a belief that there was adequate protection against the risk of boulders falling from the soil slope (paragraph 115).

138 It is probable that the following factor was causal:

- the boulder fell onto the railway before planned de-vegetation and scaling works were carried out on the adjacent rock face (**paragraph 116, Recommendation 4**).

Additional observations

139 Although not linked to the accident on 6 June 2010, the RAIB observes that:

a. The process which includes the Earthworks Prioritisation Model may not be optimised to effectively assist in the prioritisation of slopes for remedial work (**paragraph 123, Recommendation 3**).

b. For mixed ground where standard NR/L3/CIV/065 only requires a condition rating to be obtained for the predominant material, which could result in an incomplete appreciation of the overall condition of a slope being determined (**paragraph 125, Recommendation 2**).

c. The algorithm which calculates the RSHI and which then generates the rating does not always give a result that reflects a slope's true condition and the GISmo system does not permit a condition rating based on judgement. This could give rise to Network Rail not having a true appreciation of the condition of its earthworks (**paragraph 133, Recommendations 3 and 5**).

d. Lighting diffusers that dropped and in some cases became free when the train derailed could have caused injuries to those on board (**paragraph 134, Recommendation 6**).

Actions reported as already taken or in progress relevant to this report

140 Staff from a new examination contractor appointed in 2009 carried out a visual inspection following the accident to determine how the boulder came to fall and to identify any further potential for boulders to fall on to the railway in the Pass of Brander (paragraph 103). This included the clearance of sections of vegetation. The RAIB obtained a copy of the contractor's report.

141 It is clear from the report that many unsecure boulders were found on the soil slope during the post-accident inspection. These were removed so that they no longer posed a risk to the railway.

142 Network Rail brought forward the work in the business plan to de-vegetate, scale and install rock fall protection netting at sites in the Pass of Brander, including where the accident occurred.

143 Since the accident, Network Rail has made some changes to the RSHI, and further improvements are being made through national meetings of the earthworks assessment engineers.

144 Network Rail reported that, following the accident at Falls of Cruachan, it had reviewed the examination and evaluation systems. The review had focused on the consistency of condition reporting and evaluation, how vegetation was being dealt with, the policy concerning remediation works and their prioritisation, and the competency of staff. The outcome of the review was the setting up of areas of work to improve the management of earthworks. This was ongoing at the time of publication of this report.

145 First ScotRail instituted a special check on all lighting diffusers fitted to class 156 units to check operation and security of the budget locks. Additionally, all lighting diffusers were secured with tie wraps for extra security, and maintenance jobs updated to include the new requirement to prevent a recurrence of lighting diffusers falling down and possibly becoming completely detached.

Previous recommendations relevant to this investigation

146 The following recommendations, which are relevant to the factors identified in paragraph 139d, were made by the RAIB as a result of previous investigations.

Derailment near Moy, Inverness-shire, 26 November 2005, RAIB report 22/2006, published November 2006

Recommendation 9

All rolling stock owners should identify rolling stock in their ownership with a similar method of secondary retention to that of unit 170 431 (the unit involved in the accident) and carry out modifications to mitigate the risk identified in this report (in this accident, a ceiling panel fell down preventing the driver from being able to open the door between the driver's cab and the passenger saloon so that he could exit the cab).

Derailment at Grayrigg, 23 February 2007, RAIB report 20/2008, published October 2008

Recommendation 23

The *Rail Safety and Standards Board* (RSSB) should consider, and where appropriate make a proposal, in accordance with the Railway Group Standards code to implement a requirement in the relevant design standard to provide sufficient means of retention for internal panels assessed as capable of causing serious injury in the event of complete detachment.

Recommendation 24

Virgin Trains and Angel Trains should review the mounting of the reading light panels on the class 390 Pendolinos to take steps to minimise occupant injury from failure of the panel retention system.

147 Recommendation 9 of the report on the Moy derailment has been closed out by the Office of Rail Regulation, but the RAIB's information is that the recommendation was implemented only in respect of the class 170 'Turbostar' family of rail vehicles.

148 Recommendation 23 of the report on the Grayrigg derailment was closed by the updating of Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures'. This standard requires that 'access panels or equipment cubicle doors shall, so far as is reasonably practicable, be designed to resist accidental opening in service or in the event of a collision or derailment that could result in injury or hinder egress'. This is not required to be applied retrospectively to vehicles already in service.

149 Recommendation 24 of the report on the Grayrigg derailment was closed following work by Angel Trains, Virgin Trains and Alstom Transportation. This concluded that the existing design of the reading light panels was adequate, and the risk of injury to vehicle occupants was already reduced so far as is reasonably practicable and therefore in compliance with health and safety legislation. Aside from this, the design of the budget locks, used to secure the panels in place, was improved by the manufacturer providing a more effective load carrying capability.

Recommendations

150 The following recommendations are made[10]:

Recommendations to address causal factors

1 *The intention of this recommendation is to ensure that for earthworks in Scotland sufficient vegetation clearance is undertaken to allow adequate examination and evaluation of slopes to determine their condition.*

In respect of earthworks in Scotland, Network Rail should review its existing arrangements for the clearance of vegetation to enable examinations and evaluations of earthworks to be carried out. If this review indicates that the current arrangements do not enable a sufficient understanding of their condition of earthworks to be obtained, and if there is no alternative means of assessing the risks associated with such slopes, Network Rail should define the extent of vegetation clearance that is required to enable examinations and evaluations to be carried out, and then implement a strategy for achieving it (paragraph 137a).

2 *The intention of this recommendation is that where a cutting comprises mixed ground of soil and rock, all parts of the slope should be examined and reported.*

In respect of all cuttings equal to, or greater than, three metres high through mixed ground of soil and rock, Network Rail should implement arrangements so that (paragraphs 137b and 139b):

- in accordance with NR/L3/CIV/065, examination results are reported for both the soil and rock materials; and
- both the soil slope hazard index and the rock slope hazard index are reported.

continued

[10] Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation to enable it to carry out its duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 167 to 171) can be found on RAIB's website www.raib.gov.uk.

3 *The intention of this recommendation is to improve Network Rail's management of its earthworks by requiring examiners and examining engineers to give their professional judgement on the condition of earthworks; to take that judgement into account when managing earthworks; and to resolve any inconsistencies between successive condition ratings determined from the SSHI or the RSHI.*

Network Rail should amend its earthworks management system so that (paragraphs 137g and 139c):

- earthwork examiners and earthwork examining engineers record on all examination reports whether, in their professional judgement, the condition ratings determined by the SSHI and RSHI are a reasonable reflection of slope condition;
- where examiners and examining engineers disagree with the SSHI and/or RSHI condition ratings, their judgement of the slope condition rating should be recorded on the examination report and taken into account when deciding how to manage the earthwork; and
- any inconsistencies between condition ratings from successive examinations should be identified and resolved.

4 *The intention of this recommendation is to identify whether the process for planning remediation works which includes the use of the Earthworks Prioritisation Model could be changed to improve the likelihood of remedial works being carried out before failure occurs.*

In the light of experience, and the associated application of professional judgement, Network Rail should review the process for planning remediation works which includes using the Earthworks Prioritisation Model and, if necessary, make any changes to it so that the likelihood of remedial works being carried out before the occurrence of the failure of earthworks is improved (paragraphs 138 and 139a).

Recommendations to address other matters observed during the investigation

5 *The intention of this recommendation is to improve the calculation of the rock slope hazard index so that it gives a more realistic indication of a railway rock cutting's condition.*

Network Rail should review the algorithm which calculates the rock slope hazard index so that its output gives a more realistic indication of a railway rock cutting's condition (paragraph 139c).

continued

6 *The intention of this recommendation is to reduce the risk of lighting diffusers and other saloon interior panels becoming displaced and causing injuries to persons on board trains in the event of an accident.*

First ScotRail should assess the risk of lighting diffusers and other saloon panels in the interiors of trains that it operates becoming displaced in the event of an accident such that they may cause injuries to those on board. Any necessary remedial measures to reduce the risk should be implemented (paragraph 139d).

This recommendation may also apply to other train operating companies.

Appendices

Appendix A - Glossary of abbreviations and acronyms

GISmo	Geographical Information System – mobile
RSHI	Rock slope hazard index
SSHI	Soil slope hazard index

Appendix B - Glossary of terms

Bar coupler	Semi-permanent rigid connector between two vehicles of a multiple unit.
Block	A term used in this report for a piece of rock fallen from a rock cutting face.
Boulder	A term used in this report for a piece of rock currently resting on, or recently fallen from, a soil slope.
Budget lock	A simple locking device used to secure panels, doors and other similar features and operated by, for example, a square ended key.
Cess	The area along the side of the railway track.
Crankcase	The housing that contains the crankshaft of an internal combustion engine.
Danger	A signal indication or aspect meaning that the driver must driver must stop.
Diesel multiple unit	A train consisting of a number of coaches (cars) powered by diesel engines that can couple up to another diesel powered train and be driven from the cab at the leading end.
Earthworks	A collective term for cuttings, embankments and natural slopes.
Evaluation	An appraisal of information regarding the stability, condition, use and location of an earthwork to determine the actions required to maintain acceptable levels of safety and performance.
Examination	A visual inspection of an earthwork undertaken to identify and record signs of slope instability.
Flash fire	A short duration fire which can occur when fuel or other combustible material is mixed with air in sufficient concentrations for combustion to occur.
Four-foot	The area between the rails on which trains on the national network run.
Natural slope	Sloping ground that has been formed by natural processes.
On train data recorder	A data recorder fitted to a train that collects information about its performance and about the status of systems such as speed and brake controls.
Rail Safety and Standards Board (RSSB)	An independent rail industry body which manages the creation and revision of certain mandatory and technical standards (including Railway Group Standards) as well as leading a programme of research and development on behalf of government and the railway industry.
Rock slope hazard index	The Network Rail system used to derive a condition rating for rock slopes.

Root jacking	A process which occurs during the growth of tree roots resulting in the prising apart of rocks or the displacement of boulders.
Secondary retention	An independent means of restraining a piece of equipment should the primary means of attachment fail.
Soil slope hazard index	The Network Rail system used to derive a condition rating for soil slopes.
Scaled	The planned removal of unstable boulders and rock from an earthwork so that they are no longer a hazard.

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